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Preliminary results of a taphonomic study of a vertebrate accumulation from the Tetori Group (Lower Cretaceous) of Japan

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Abstract. A predominantly microvertebrate assemblage from the Tetori Group (Lower Cretaceous) of central Honshu is described. The fauna consists of many hundreds of vertebrate fossils which represent a diverse terrestrial/non-marine fauna. Taxa present include fish, reptiles, amphibians and birds. The preservation of the fossils is generally good, although there are few articulated and associated remains.

Key words : Japan, Lower Cretaceous, Tetori Group, Vertebrates

Introduction

Neocomian vertebrate fossils have been described from a variety of localities in central Honshu, Japan. The first of these sites to be described, Kasekiheki, Shiramine Village, Ishikawa Prefecture, yielded a carnosaur tooth and dinosaur footprints (Manabe *et al*., 1989). More recent fieldwork has increased the numbers and taxonomic range of fossils from the Tetori Group, for example, iguanodontid teeth from Shiramine (Hasegawa *et al*., 1995), a hypsilophodontid tooth from Gifu Prefecture (Hasegawa *et al*., 1990), an incomplete pterosaur wing phalange from Shokawa, Gifu Prefecture (Unwin *et al*., 1996), and crocodile remains from Katsuyama, Fukui Prefecture (Manabe *et al*., 1989).

Over recent years a series of excavations at a stream section in Gifu Prefecture has produced many hundreds of vertebrate fossils, representing fish, turtles, dinosaurs, frogs, choristoderes, salamanders and birds.

Geological setting and locality

The Tetori Group outcrops in central Honshu (Figure 1). It ranges in age from Middle Jurassic to Early Cretaceous (Maeda, 1961). The outcrops are generally of limited extent, due to the lush vegetation, and are often found in stream sections or road cuttings. The Tetori Group sediments (conglomerate, sandstone and mudstone) form part of the Hida Terrane. The terrane is mainly composed of igneous and metamorphic rocks (Maeda, 1961).

The Tetori Group is subdivided into the Kuzuryu, Itoshiro and Akaiwa Subgroups (Maeda, 1952). The oldest, Kuzuryu Subgroup ranges from Bajocian to Oxfordian in age and is composed mainly of conglomerate, shales and sandstones. The Itoshiro Subgroup is Kimmeridgian to Berriasian in age and is also composed predominantly of conglomerates, sandstones and shales. The youngest Akaiwa Subgroup is Valanginian to Albian in age. It comprises conglomerates, arkosic sandstones, shales and occasional tuffs (Maeda, 1961).

The vertebrate materials described here come from site KO-2 (36°03′N, 136°53′E) close to Shokawa Village, Gifu Prefecture (Figure 1). The dominant lithologies are alternating fine- and coarse-grained sandstones and mudstones. These sediments form part of the lowest section of the Okurodani Formation (upper part of the Itoshiro Subgroup) and are of Lower Cretaceous age (Manabe and Hasegawa, 1995 ; Hasegawa *et al*., 1995) ; and were stratigraphically placed by non-marine fossils (Maeda, 1961) and dated at 140-120 Ma by fission track analysis (Gifu-Ken Dinosaur Research Committee, 1993).

Vertebrate fauna

To date some 800 specimens have been recovered, prepared and described from Shokawa site KO-2. A variety of taxa has been identified.

The most common elements of the fauna are fish (Figure 2). Most of these fossils are preserved as isolated scales, vertebrae and bone fragments. Turtle remains are also common, mostly preserved as isolated dermal material and bones, although some associated and articulated specimens have been discovered. Less common taxa include choristoderes, lizards, frogs, salamanders, dinosaurs and birds. The choristodere is the earliest record from Asia east of Inner Mongolia (Manabe and Hasegawa, 1995).

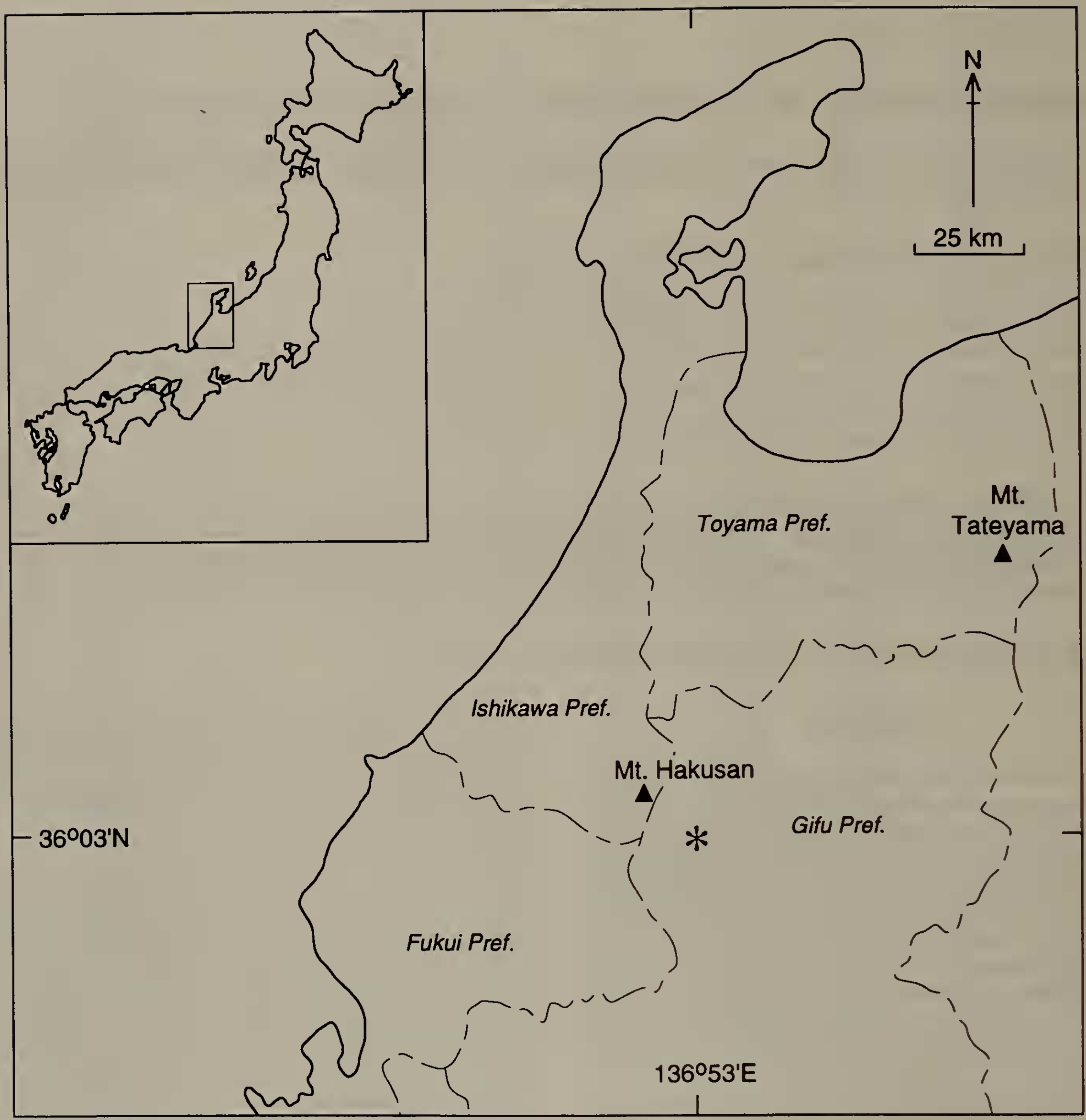

Figure 1. Location of Shokawa Village site KO-2 (Lower Cretaceous), Gifu Prefecture, marked with*.

Vertebrate taphonomy

The vertebrate debris comes from a layer no more than 200 mm thick, located in a thick sequence of siltstones, sandstones and occasional volcanic tuffs. The bone bed is a dark grey silty sandstone. Fossils are not evenly distributed through this horizon; rather they occur in well-defined layers (Figure 3).

The bottom of the bed is marked by large plant fossils. This is overlain by a concentration of shell debris (including fresh water unionid bivalves and viviparid gastropods) and bones. Generally, the scales and bone fragments occur in the lower parts of this concentration. The better preserved and associated materials (e.g., turtles and choristodere fossils) occur towards the top. A few tens of millimetres of barren sediment separates this bone concentration from a layer containing dinosaur teeth at the very top of the bed. The discrete layers of fossils probably represent a combination of taxonomic and hydrodynamic sorting. This is the only evidence of sedimentary structures found in the bone-bed horizon.

A series of taphonomic characters were described for the KO-2 fossil collections. Each bone or tooth fragment was described according to its state of abrasion and weathering; and the degree of fragmentation and nature of fractures present.

Fiorillo (1988) formulated a descriptive classification scheme for vertebrate materials:
Stage 0-Very angular: the bone (or tooth) is fresh and unabraded. Processes and bone edges are sharp and well-

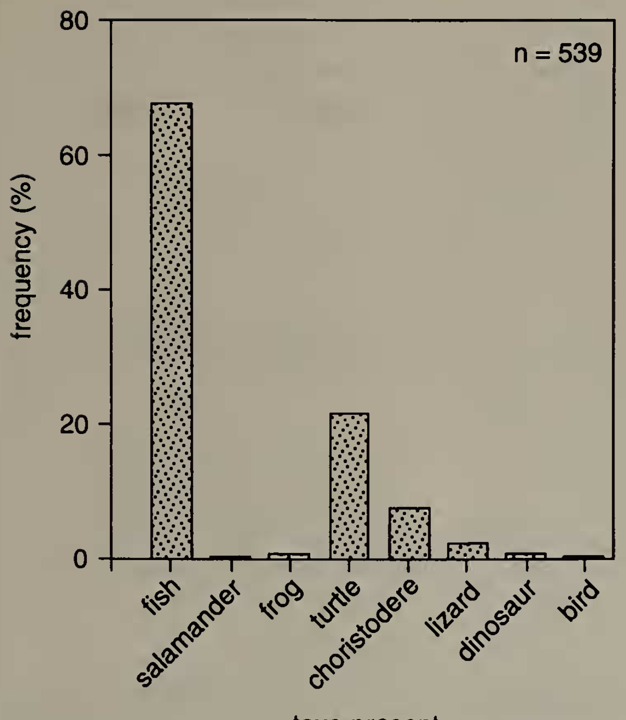

Figure 2. Relative proportions of identifiable fossils from site KO-2. 229 unidentifiable bone fragments were recorded.

defined.

Stage 1-Subangular: the bone processes and edges are slightly abraded and polished.

Stage 2-Subrounded: the bone edges are well rounded, processes are still recognisable. This stage is characteristic of moderate abrasion.

Stage 3-Rounded: edges show a high degree of rounding, processes are generally remnant.

It is necessary to include a final stage:

Stage 4-Extreme rounding, often spherical (Cook, 1995).

This scheme is discontinuous; abrasion characteristics are continuous, therefore intermediate stages are included (Cook, 1995).

Classically, the abrasion state relates to the distance a bone fragment has travelled in a fluvial system. However, it is more realistic to consider that the rounding is produced by a combination of physical processes (transport in rivers and the effects of trampling by animals) and reworking.

The material from KO-2 covers the full spectrum of possible abrasion stages (Figure 4). The majority of the materials range from stage 0-1 to stage 1-2, characteristic of slight abrasion. The range of abrasion stages indicates that the fossil assemblage is attritional rather than catastrophic in origin.

Changes in temperature and relative humidity modify bones as they lie on the ground prior to burial. These modifications take the form of cracks, initially on the outer layers of tissue, then working inwards until the bone breaks into a series of indeterminate fragments (Behrensmeyer, 1978; Fiorillo, 1988). The KO-2 specimens were examined and no evidence of *in situ* weathering modification was found.

Many of the KO-2 fossils are incomplete, that is they have been broken at some point between death and description. In most cases it was not possible to determine the relative timing of these fractures. Most of the identifiable fractures appear to be post-mineralisation; although pre-mineralization fractures and breakages caused during preparation are also present.

The fractures expose internal structures of the bones, often revealing cavities that have been infilled with white, cream or yellowish minerals. The nature of these mineral infills has yet to be determined.

Although the bulk of the collection comprises isolated skeletal elements, some associated and articulated fossils have been discovered. For example, an almost complete articulated (but crushed) turtle carapace and plastron, and an associated partial skeleton of a choristodere.

Discussion

The vertebrate fossils from the Tetori Group KO-2 site are generally characterised by a lack of modification caused by *in situ* weathering, slight abrasion, disarticulation and fragmentation. The absence of evidence for *in situ* weathering suggests that the bones were either buried rapidly, or quickly transported into rivers, where the sediment and water afforded protection from fluctuating environmental conditions. The full range of abrasion states indicates that the bone assemblage accumulated over an extended period of time, rather than during a catastrophic event. The generally low levels of rounding (abrasion) suggest that any transport affecting the bones was minimal. Few confirmed pre-mineralization fractures support this.

The majority of specimens recovered so far occur as isolated skeletal elements. Disarticulation results from a variety of processes, for example scavenging and fluvial transportation. It is likely that a combination of physical and biological processes resulted in the disarticulation state of the KO-2 fossil. Articulated and associated remains are restricted to turtle and choristodere fossils, perhaps explained by their semiaquatic lifestyles. If these creatures died in water, it is possible that they were rapidly covered by a protective layer of sediment. Fish dying in fluvial systems generally disarticulate, so scales and isolated bones are preserved (Wilson, 1996; Cook, 1997).

All of the above ties in well with our current understanding of the palaeoenvironments represented by the lithological and palaeontological records of the Tetori Group, and specifically site KO-2. The environment of deposition was terrestrial with a predominance of fluvial channels. In many respects it is comparable with the classic Lower Cretaceous Wealden sediments of southern England (Allen, 1981, 1990). However, major differences exist between the KO-2 fauna and that of the Wealden beds. Namely, the absence of crocodiles and mammals at KO-2. The lack of crocodile remains is unusual for a wetland environment, and is possibly explained by a taphonomic bias, or that the fossils haven't

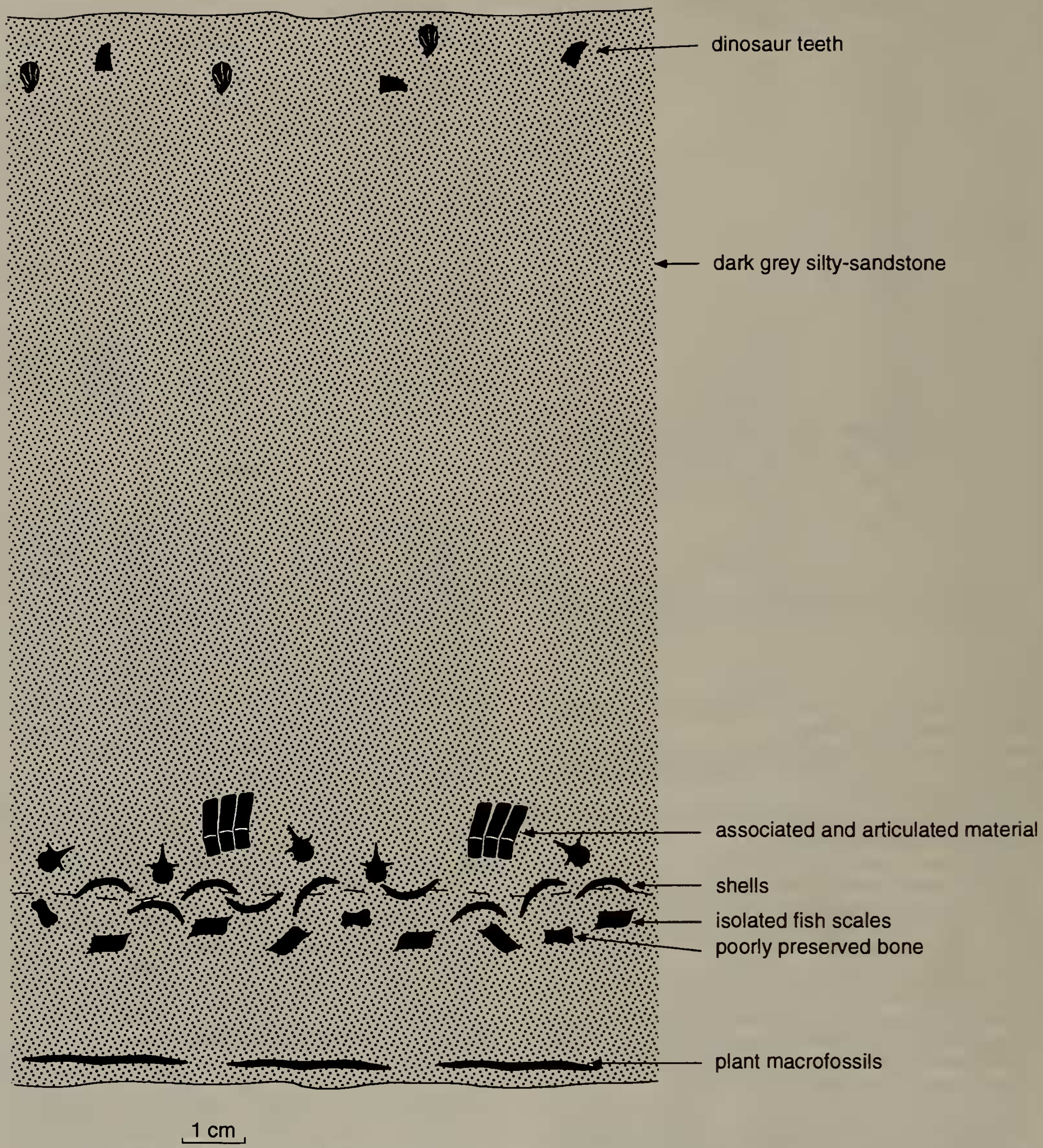

Figure 3. Schematic cross section of the bone-bearing horizon at Shokawa site KO-2, clearly showing the discrete levels of plant and vertebrate fossil materials.

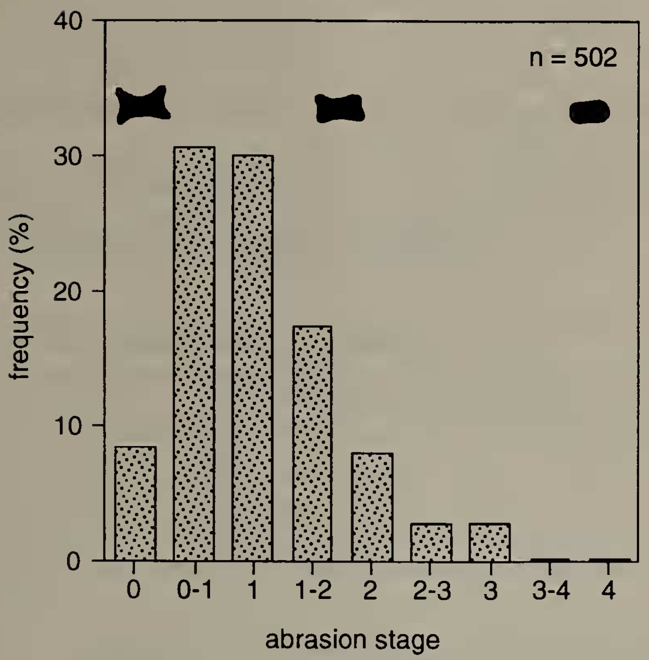

Figure 4. Abrasion states of the Shokawa site KO-2 vertebrate fossils. Classification scheme based on Fiorillo (1988) and Cook (1995).

been found yet, or a real absence of crocodiles in this part of Japan during the early Cretaceous. Perhaps choristoderes filled the 'crocodile-type' ecological niches. In contrast, the early Cretaceous environment of southern England supported several crocodile species (Buffetaut and Ford, 1979; Buffetaut and Hutt, 1980; Buffetaut, 1983; Cook and Ross, 1996). The absence of mammals is less strange; mammal fossils are very rare in the Wealden sediments (Clemens and Lees, 1971).

Conclusions

The vertebrate fossils from the Tetori Group, locality KO-2, give a valuable insight into the palaeoecology of Japan during the early Cretaceous. The site is also significant in that it has produced the oldest dinosaur fauna from Japan, and the earliest record of a choristodere for eastern Asia (Manabe and Hasegawa, 1995).

The taphonomic characteristics of the fossils suggest a post mortem history of limited transport and reworking, rapid burial in fluvial sediments before diagenetic alteration and mineral infill.

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